

A NEW TOOL FOR DELAY DISTORTION CONTROL

Notes on delay distortion and how it can be controlled by data system, common carrier and communications center engineers.

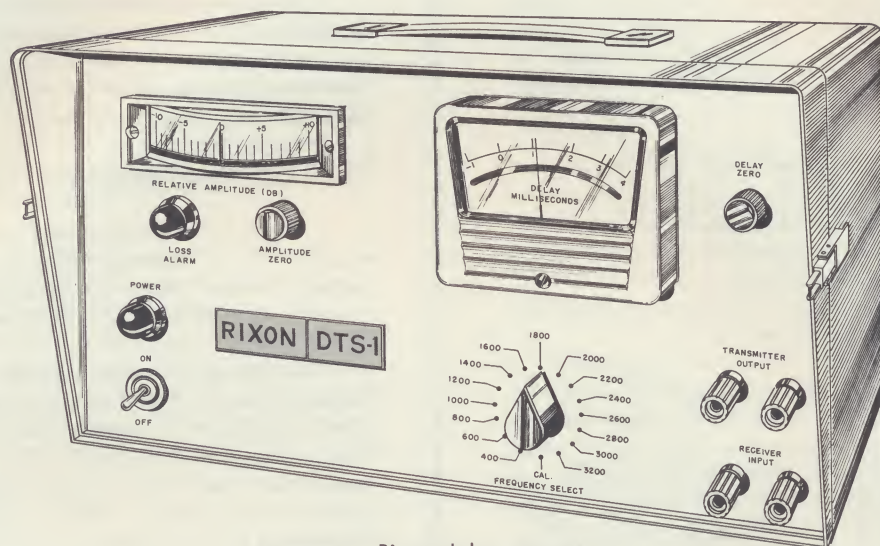


Figure 1. Rixon delay test set.

Introduction

To control delay distortion, it must be measured. The new measurement tool is the Rixon Delay Test Set, the DTS-1 pictured in figure 1. It measures delay distortion more quickly and easily than has been possible in the past. The operational advantages of the DTS-1 are detailed in this bulletin. These advantages should be of particular interest to the data systems engineer using modems, the phone company engineer who must check voice circuits for delay distortion, and the communications center engineer who must maintain a number of voice circuits.

The simplicity of the DTS-1 also makes it possible to develop a real time display of delay distortion to facilitate delay equalizer adjustments.

Delay Distortion - What is it?

Delay distortion is the result of that characteristic of a voice circuit which delays some frequencies more than others. It is the most limiting impairment in the transmission of digital data over phone lines. Because the ear is not sensitive to such distortion, very little consideration of this parameter has been given in the past.

When we want to use these voice channels to transmit digital data, delay distortion becomes very important.

Delay distortion is the name given to variations in the envelope delay of a voice circuit as a function of frequency. Envelope delay (T_d) is defined by the equation

$$T_d = \frac{d\phi}{dw}$$

where ϕ = phase shift

$$w = 2\pi \times \text{frequency}$$

and is the rate of change of phase as a function of frequency. When a line has delay distortion it means that its envelope delay is not flat. In other words, T_d is not constant. The delay characteristic of a typical voice circuit is shown in figure 2.

When digital data is transmitted over a voice circuit, delay distortion causes "intersymbol interference." This means that any given bit of data will affect the bits following it. When the effect is great enough, errors are made in the detection of the bit. A bit which was transmitted as a "one" can be received as a "zero."

One solution to this problem is to transmit data so slow that the effect of one bit on another is diminished to an acceptable level. But this is not desirable for we want to transmit data as fast as possible. The alternate solution is to improve the voice circuit. This improvement can be made by equalizing the delay distortion. The best voice circuit is one that has flat envelope delay over the widest range of frequencies.

Equalization of the circuit is accomplished by measuring the delay distortion and inserting a network in series with the circuit which compensates for the delay distortion. These networks can be fixed or adjustable and are called "delay equalizers." Today it is almost an art to equalize a voice circuit. It requires highly skilled technicians with considerable experience and training.

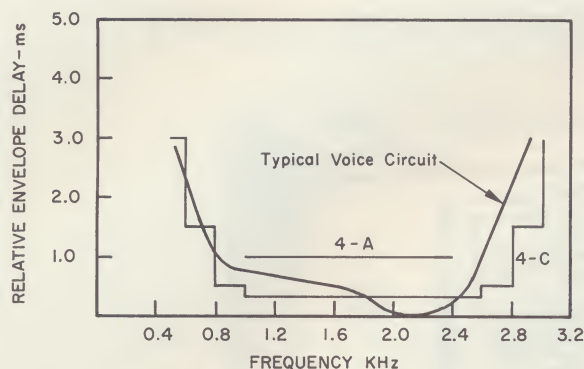


Figure 2. Delay distortion on a typical voice circuit intended for data transmission.

The Data System Engineer

The data system engineer becomes aware of the importance of delay distortion when he seeks data sets or modems to transmit digital data over voice circuits. He finds, for instance, that modems can transmit 2400 bits per second over a Type 3003 (4-A) voice circuit or 4800 bits per second over a Type 3005 (4-C) circuit. The designations Type 4-A and 4-C are phone company specifications for voice circuits, the 4-C line having better equalization for delay distortion and costing more than the 4-A circuit.

The delay distortion specification for the 4-A and 4-C voice circuits are illustrated in figure 2. The 4-A line is specified to have less than 1 millisecond variation in envelope delay between 1000 hertz and 2400 hertz. The 4-C line spec encompasses the frequency range from 500 hertz to 3000 hertz and is more complex. The typical line shown in figure 2 easily meets the 4-A spec but does not meet the 4-C spec. In order to meet the 4-C spec the line characteristics would have to be completely outside the curve labeled 4-C.

By analyzing the system costs of the 4-A line 2400 bps combination versus the 4-C line 4800 bps combination, and weighing these costs against his requirements, the data system engineer selects a suitable system. He installs this system and transmits data.

Later, system malfunctions may occur and data is received in error. Either the modem or the voice circuit may not be working properly. This engineer wants to quickly isolate the trouble so that corrective action can be taken.

Many modems have built-in diagnostic capabilities. If the trouble appears to be in the communication circuit, the line must be checked. The phone company will check the line on request, but the service response often involves considerable delay. A useful instrument for this engineer would be a test unit which he could operate himself. If such a device could quickly evaluate the circuit then the engineer would be well on his way towards getting his system back in operation.

The Telephone Company Engineer

One of the most difficult tasks the telephone company engineer has is checking a voice circuit for delay distortion. When a customer requests that a circuit be tested because he is unable to transmit data, the phone engineer must arrange for another engineer to be at the other end of the line. He must also reserve an additional line so he can maintain voice communication with this engineer.

A useful instrument for the phone company would be one that did not require continuous coordination between the two ends of the circuit. This coordination is the most time consuming aspect of the measurement. In addition the instrument should be portable.

The Communication Center Engineer

The communication center engineer often has the responsibility to maintain voice circuits in suitable condition to transmit data. He does this by equalizing the voice circuits and checking them daily.

At the center, data is put on the voice circuits or received from the voice circuits. In addition it acts as a switching point for communication between other centers. This is illustrated in figure 3. For example, if data is transmitted from center "A" to center "E" it must go through other centers. The exact path from "A" to "E" is determined by the loading of circuits in the network. If the links from "A" to "C" are all busy, then the data would be sent through centers "B" and "C", and then to "E."

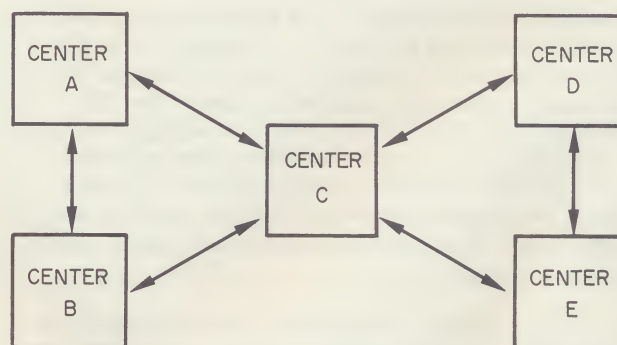


Figure 3. Simple network of communications centers.

Because the exact path for data between two centers is not defined, each intercenter voice link must have very little delay distortion. This is accomplished by equalizing each link very precisely.

In order to maintain these high quality links, the communication center engineer would like to check each link daily. As mentioned previously, the measurement of delay distortion requires several hours per circuit. The engineer with the responsibility for large numbers of circuits, finds the time required prohibitive.

There is another problem associated with communication centers; a shortage of skilled maintenance personnel. And to compound the problem, many of the people in the center are military personnel who are rotated frequently and the value of their experience they acquire during the assignment is lost.

An ideal test set for the communication center would be one that could be used to measure delay distortion and frequency response quickly and easily.

Equalizing Data Circuits

When the communication center engineer checks his voice circuits for delay distortion and finds one that is out of specification, he then has the problem of re-adjusting his delay equalizers. He does this by repeated measurement and adjustment. Since the measurement is time consuming, and repeated measurement is required, this readjustment may take a day or more. During this time, the data circuit is unusable.

In this process of equalizing a circuit, the technician must plot the measurements before he knows what adjustment to make. This step could be eliminated if a real time plot of delay distortion was available. With an automatic plot of delay distortion, the technician could make his equalizer adjustment while monitoring the display. The key to a real time plot is a delay test set which measures the entire frequency spectrum rapidly.

Delay Measuring Sets

A number of delay measuring sets are in use today. These sets are characterized by point by point measurement with frequent adjustments. It is the repeated adjustments which are time consuming and require the sets to be operated by experienced persons.

The delay measuring set which has been used most extensively to date requires voice coordination between operators at each end of the voice circuit. Operation of this set is so complex that several hours are often required to make a measurement. In addition the unit is expensive and weighs over 65 pounds.

One recently developed delay measuring set is a portable field unit but requires an additional voice circuit to return the delay set's measurement reference. This means that two circuits are tied up.

Another delay measuring set on the market is also portable, however it also requires two voice circuits in order to make a measurement. The difference between this set and the set mentioned above is that the additional voice circuit required must be in the same direction as the circuit under test.

All of these sets mentioned require continuous adjustment and therefore require considerable time to make a measurement.

The delay measuring set which would satisfy the

needs of the data systems engineer, phone company engineer, and communication center engineer would have the following characteristics:

answer available instantly

skilled operators not required

no additional circuits are required

operators not required at each end of the circuit

portable, lightweight, and used easily in the field

In addition it would facilitate equalizer adjustment if a real time display of delay distortion was available.

The DTS-1 Delay Test Set

The Rixon DTS-1 Delay Test Set was developed specifically to meet these requirements. The salient feature of this set is its ease of operation. This can best be illustrated by referring to the front panel controls figure 1. The unit shown contains both a transmitter and a receiver.

To operate the DTS-1 as a transmitter, the only actions required are to connect the output to the voice circuit and to turn on the unit. The set can operate as a transmitter simultaneous with operation as a receiver. The transmitter and receiver share no circuitry other than the power supply.

The operation of the receiver is easy. After turning on the set, the operator checks the zero adjust of the envelope delay meter and the relative amplitude meter while in the calibrate position. He then rotates the frequency select switch through the other 15 positions. At each position of the switch, he notes or records the readings of the envelope delay meter. The operator then has measured the delay distortion of the voice circuit. It can be accomplished in a few minutes.

While measuring the delay distortion, the operator should monitor the relative amplitude meter. The meter face is divided into red and green portions. When the indicator is in the green portion of the scale, the voice circuit is in spec for relative amplitude. When the indicator is in the red portion, then the circuit is out of spec.

Although the relative amplitude meter is intended as a monitoring device it is used to measure relative amplitude across the band. Its accuracy is ± 0.5 db.

Figure 4 shows a diagram of the DTS-1 connected to a voice circuit. At the transmitter end (location A) the action required is so simple that no operator is needed at that end. All controls necessary to make a measurement are at the receive end (location B).

Because the DTS-1 sends its reference information along with its signal, no other voice circuit is required.

Referring again to figure 1, the front panel illustration, note the loss alarm light. This alarm senses when the received signal is out of the level range of the device. This avoids erroneous readings. When the line signal is too low for the DTS-1, it is also not usable for transmitting data.

The DTS-1 is a lightweight portable unit making it ideal for field use. The weight of the transmitter and receiver in its carrying case is approximately 20 pounds. The unit measures 10" high, 9" deep, and 16" wide (including cover).

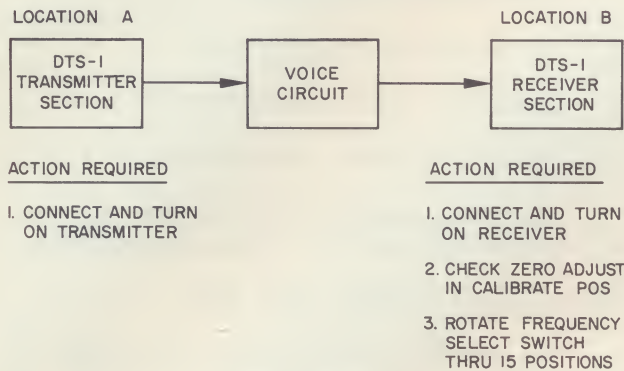


Figure 4. Delay Test Set phone line connections and actions required for operation.

Principle of Operation

The DTS-1 utilizes a new technique for generating a test signal. The signal which is generated contains energy at every 200 hertz across the band of interest. The band of interest is defined as 400 hertz to 3200 hertz. This signal is modulated by a 50 hertz sine wave. The output spectrum of the DTS-1 is shown in figure 5.

The receiver accepts this signal and extracts a 50 hertz reference signal from the energy at 1600 hertz. As the frequency select switch is rotated, the receiver also extracts another 50 hertz signal. This other 50 hertz signal has experienced the envelope delay of the selected frequency as indicated by the frequency select switch. By comparing the relative phase of the two 50 hertz signals, the relative envelope delay is determined. The delay indicated on the front panel meter is the relative envelope delay between 1600 hertz and the selected frequency.

Simultaneously with the delay measurement, relative amplitude is measured. This is accomplished in the receiver by measuring the signal level at the selected

frequency while the delay measurement is being made. The quantity indicated on the relative amplitude meter is the level of the selected frequency relative to midband (1600 hertz). The relative amplitude measurement can be made relative to other frequencies (i.e. 1000 hertz). This is accomplished by setting the meter zero while the frequency select switch is at the desired frequency.

When the received line signal is too low (below -30 db) the loss alarm light is lighted. Although the DTS-1 can operate below this level, its accuracy cannot be guaranteed.

The Display Generator

To fulfill the need for a real time display of delay distortion to facilitate equalization of voice circuits, Rixon currently has under development the DDG-1 Delay Display Generator. Because of the techniques used in the DTS-1, the design of this unit is straightforward. When interconnected with the DTS-1 and a general purpose oscilloscope as shown in figure 6, it is capable of generating a real time scope display of delay distortion as illustrated in figure 7. By observing this scope picture while adjusting the delay equalizer, the engineer can quickly adjust the voice circuit for best performance.

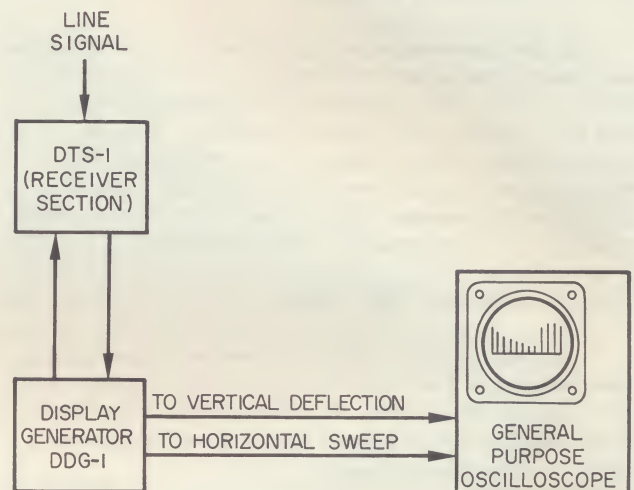


Figure 6. Simplified block diagram showing the DTS-1, Display Generator and General Purpose Oscilloscope interconnected.

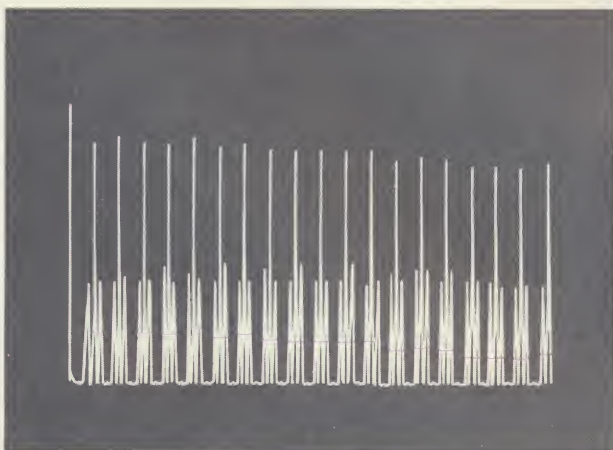


Figure 5. DTS-1 transmitter output spectrum.

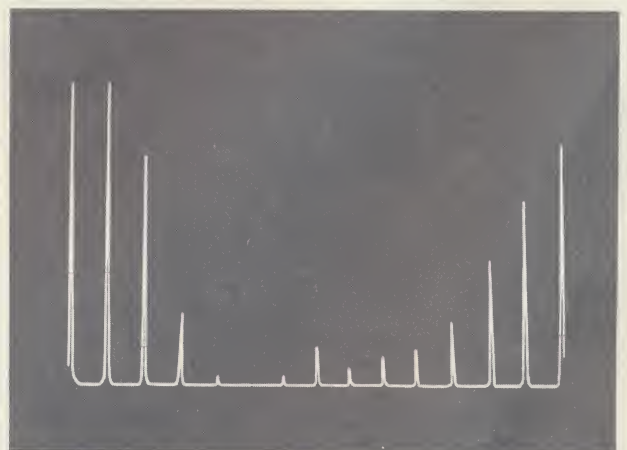


Figure 7. Typical scope display of DDG-1 output.

Future Developments

Also under development by Rixon is an automatic delay equalizer built around the DTS-1. This device will be especially valuable to the data system engineer who must frequently switch circuits.

Conclusions

The characteristics of the DTS-1 make it a practical test instrument to answer the growing need for delay distortion measurements.

The advantages of the DTS-1 are:

answer available quickly

does not require skilled operators

requires no additional circuits

requires operator at receive end only

portable package ideal for field use.

In addition to providing a fast evaluation of delay distortion, it also gives evaluation of:

amplitude distortion

line loss

When the DDG-1 Delay Display Generator is used with the DTS-1 and a general purpose oscilloscope, it is possible to display delay distortion in real time to facilitate equalization of voice circuits.

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